

OPTIMIZATION OF AMPLITUDE CHARACTERISTICS OF  
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TRANSMISSION OF IMAGES

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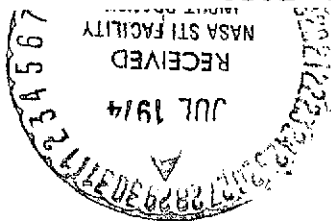
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16. Abstract  An examination is made of the problem of optimizing amplitude characteristics of applied systems of electric image transmission. It is concluded that the contrast sensitivity of applied systems of electric image transmission must be characterized by the total different halftone gradations, and by the change in contrast sensitivity over the dynamic range of the transmitted image.			
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OPTIMIZATION OF AMPLITUDE CHARACTERISTICS OF  
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V. D. Glazkov and A. S. Yefimov

An examination is made of the problem of optimization of  
amplitude characteristics of applied systems of electric image  
transmission, based on two criteria: maximum contrast sensitivity  
of the system (maximum number of different halftone gradations)  
and the required nature of the change in the contrast sensitivity  
in terms of the dynamic range of the image being transmitted with  
a maximum possible number of different gradations. / 2\*

In the first case, the optimum amplitude characteristics  
are found by solving the variational problem with an unconditional  
extremum (maximum) of the integral reflecting the dependence of  
the total number of different gradations on the contrast sensi-  
tivity of the receiver. In the second place, they are found by  
solving the variational problem for a conditional extremum,  
and the communication equation is formulated on the basis of the  
necessary nature of the change in the contrast sensitivity of the  
system in terms of the dynamic range of the image being trans-  
mitted. /3

The influence of the amplitude characteristics of the com-  
ponents of a system of electrical image transmission (EIT) upon

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\* Numbers in the margin indicate pagination of original  
foreign text.

the quality of the image is well known. In applied systems, where it is frequently necessary that the visual impressions from the received and transmitted image are the same, the criterion for the optimum amplitude characteristics may be a determination of their influence upon the system contrast sensitivity [1].

The contrast sensitivity (CS) is one of the most important characteristics of the EIT system, which makes it possible for the receiver to detect low-contrast objects in the image being transmitted by means of the system. Usually it is determined by the total number of gradations of halftones which are different in the image received. However, this number does not characterize the system CS completely. In addition it is necessary to know the manner in which the CS changes over the dynamic range of the image being transmitted.

The total number of gradations of halftones which differ in the dynamic range of images from  $B_{\min}$  to  $B_{\max}$  is expressed by the integral [2]:

$$m = \int_{\lg B_{\min}}^{\lg B_{\max}} \frac{d(\lg B)}{f(\lg B)} \quad (1)$$

where  $f(\lg B) = K_n$  is a function characterizing the contrast sensitivity of the receiver, i.e., the change in the threshold differential  $(\Delta \lg B)_t$  with respect to the dynamic range of the image.

We should note that

$$(\Delta \lg B)_t = \lg(B + \Delta B_t) - \lg B = \lg(1 + \Delta B_t/B), \quad (2)$$

where  $\left[ \frac{\Delta \beta_t}{\beta_t} \right]$  is the threshold contrast, and for small  $\left[ \frac{\Delta \beta_t}{\beta_t} \right] \sim \left[ \frac{\Delta \lg B}{\lg B} \right] \sim \left[ \frac{\Delta D}{D} \right]$

Let us consider an EIT system in the form shown in Figure 1.

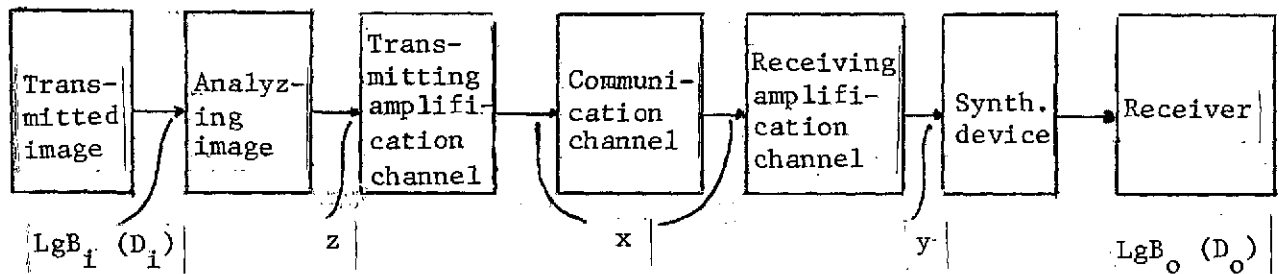


Figure 1.

If the contrast sensitivity of the receiver  $K_R$ , the amplitude and halftone characteristics of the EIT system components are known, then the contrast sensitivity of the system  $K_C$  may be approximately determined from the following expression (in the case of a linear communication channel):

$$K_C \cong \frac{K_R}{|f'_1 f'_2 f'_3 f'_4|} = \frac{K_R z'_1}{|f'_1 y'_3 f'_4|},$$

Reproduced from  
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where  $f'_1$  is the curvature of the halftone analysis characteristic

$$z = f_1(\lg b_1) \quad \text{or} \quad z = f_1(D_1),$$

where  $f'_2 = \frac{f}{z'_x}$  - is the curvature of the amplitude characteristic of the transmitting amplification channel  $x = f_2(z)$ ;  
 $f'_3 = y'_x$  - curvature of the amplitude characteristic of the receiving amplification channel  $y = f_3(x)$ ;

- $f_4'$  - curvature of the halftone synthesis characteristic  $\lg B_0 \cdot |f_4(y)|$  or  $B_0 \cdot |f_4(y)|$
- $x, y, z$  - are the standardized values of the instantaneous values of the electric signal. /5

It is known that the vision CS (when the receiver is a human being) depends not only on the brightness of the signal, but also on its angular dimensions, brightness and angular dimensions of the background, as well as on the noise characteristics of the image. If the noise at the output of the analyzing device and in the communication channel is known, then the noise level in the output image may be approximately determined by the expression

$$\delta_0 \approx y_4' \cdot |f_4'| / \sqrt{\left(\frac{\delta_2}{z_1}\right)^2 + \frac{1}{\gamma_k}} = \psi_2(y, y', z, z'), \quad (4)$$

where  $\delta_0$  is the effective noise value in the output image,

$\delta_2 = \psi(z)$  - standardized effective value of noise at the output of the analyzing device;

$\gamma_k$  - signal-noise ratio in the communication channel.

Thus, the receiver contrast sensitivity  $K_H = f(\delta_0) \cdot |y, y', z, z'|$  and expression (1) for the total number of gradations assumes the form:

$$m = \int_{\delta_0 \min}^{\delta_0 \max} \frac{d(\lg B_0)}{f(\lg B_0) \cdot |y, y', z, z'|}.$$

Changing to different variables, we obtain

$$m = \int_{y_1}^{y_2} \frac{|f_4'| \cdot dy}{f(y, y', z, z')} = \int_{x_1}^{x_2} \frac{|f_4'| \cdot y' \cdot dx}{f(y, y', z, z')}, \quad (5)$$

where  $y_1 = y_{\min}$ ,  $x = x_{\min}$ ,  $y_2 = x_2 = 1$  if  $f_4' \neq 0$ .

It is now possible to formulate the first problem in terms of optimization of the amplitude characteristics of the amplification channel of the EIT systems: When the noise of the analyzing device and the communication channel is known, the amplitude characteristics of the transmitting and receiving channels must provide the maximum number of different halftone gradations expressed by the functional (5).

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The problem formulated is a variational problem, and its solution may be reduced to solving a system of two Euler equations [3]:

$$\left. \begin{aligned} F_y - \frac{d}{dx} F_{y'} &= 0 \\ F_z - \frac{d}{dx} F_{z'} &= 0 \end{aligned} \right\} \quad (6)$$

where  $F = \frac{f_0(y, z)}{f(y, y', z')}$  is the integrand of (5),

$F_y, F_z, F_{y'}, F_{z'}$  - are the partial derivatives of the function  $F$ .

Since the integrand  $F$  does not contain in explicit form the variable  $x$ , the system (6) may be somewhat simplified

$$\left. \begin{aligned} F - y' F_{y'} &= C_1 \\ F - z' F_{z'} &= C_2 \end{aligned} \right\}$$

where the constants  $C_1$  and  $C_2$  are found from the boundary conditions for the desired characteristics.

A particular case of the problem being considered is the case when the amplitude characteristic of the transmitting channel  $x = x_1(z)$  is given. It is necessary to find the amplitude characteristic of the receiving channel which maximizes the total number of different halftone gradations. Thus, in expression (4) the term  $\frac{dx}{dz}$  may be expressed by  $x$ , and the functional (5) assumes the form

$$m = \int_{x_1}^{x_2} \frac{f_0(y, z)}{f(x, y, y')} dx \quad (7)$$

The amplitude characteristic  $y=f(x)$ , maximizing this functional is the solution of the Euler equation

$$F_y - \frac{d}{dx} F_{y'} = 0,$$

where  $F = \int_{x_1}^{x_2} f(x, y, y') dx$  is the integrand of the functional (10).

Maximizing the total number of different halftone gradations, we have not yet considered the nature of the change in the contrast sensitivity over the dynamic range of the image being transmitted. The second problem of optimization of the amplitude characteristics may be formulated as follows: when the noise of the analyzing device and the communication channel is known, the amplitude characteristics of the transmitting and receiving channels must provide the necessary nature of the change in the contrast sensitivity over the input dynamic range with a maximum possible number of different halftone gradations.

A comparison of this problem with the preceding problem shows that, if the former is a variational problem for an unconditional extremum, the latter is a variational problem for a conditional extremum, and the communication equation contains the condition providing the necessary nature of the change in the contrast sensitivity. We shall find this communication equation.

Let us assume that the CS change with respect to the dynamic range of the image being transmitted is given by the standardized function  $\varphi(\lg B_i)$  so that

$$K_c = a \cdot \varphi(\lg B_i), \quad (8)$$

where  $K_c = (\Delta \lg B_i)_t$  - is the threshold value of the input brightness signal, which must be detected by the receiver in the output image;

a - is a constant.



Equating expressions (3) and (8), we find the desired communication equation

$$a \cdot \varphi_1(\lg B_1) = \frac{K_r z'}{x' y' |x'|}$$

or

$$a \cdot \varphi_2(z) - \frac{f(y, y', z, z') \cdot z'}{y' |x'|} = \varphi(y, y', z, z') = 0, \quad (9)$$

where  $\varphi_2(z) = \varphi_1(\lg B_1) |x'|$ .

The quantity  $K_r = f(y, y', z, z')$  is the contrast sensitivity of the receiver.

Thus, this problem consists of finding the functions  $y(x)$  and  $z(x)$ , which maximize the functional (5) and satisfy the communication equation (9).

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It is known [3] that the conditional extremum of the functional

$$V = \int_{x_1}^{x_2} F(x, y, y', z, z') \cdot dx$$

when the communication equation holds

$$\varphi(x, y, y', z, z') = 0$$

is obtained for the same curves  $y(x)$  and  $z(x)$  as the unconditional extremum of the functional

$$V^* = \int_{x_1}^{x_2} F^* dx,$$

where  $F^* = F + \lambda(x) \varphi$

$\lambda(x)$  - is a certain function.

Consequently, the solution of the latter problem consists of solving a system of two Euler equations:

$$\left. \begin{aligned} F_y^* - \frac{d}{dx} F_{y'}^* &= 0 \\ F_z^* - \frac{d}{dx} F_{z'}^* &= 0 \\ \varphi(y, y', z, z') &= 0 \end{aligned} \right\} \quad (10)$$

supplemented by the communication equation (9)

Thus, the second problem of finding the amplitude characteristics of the transmitting and receiving channels of an EIT system, which provides the necessary nature of the change in the contrast sensitivity when there is a maximum possible number of different halftone gradations, represents the most general problem, which leads to the first problem when there is no communication equation. In addition, the problem of providing only a given change in the CS, when it is necessary to solve one communication channel of Equation (9), and also the problem of finding the amplitude characteristics of one receiving channel (with a given characteristic of the transmitting channel), which provides the necessary change in the CS over the dynamic range of the input image, represent particular cases.

Thus, to find the optimum amplitude characteristics of the amplification channels of an applied EIT system, it is necessary to determine the change in the contrast of the objects, which must be detected by means of the system, the characteristics of the analysis and synthesis of the halftones and it is necessary to know the nature of the noise at the output of the analyzing device and the receiver CS. During the solution of the system (10) not only the desired amplitude characteristics of the transmitting and receiving channels may be found, but also the signal-noise ratio in the communication channel which is necessary to provide the necessary contrast sensitivity of the system.

### Conclusions:

1. The contrast sensitivity of applied systems of electric image transmission must be characterized both by the total number of different halftone gradations, and by the nature of the change in the contrast sensitivity over the dynamic range of the image being transmitted.

2. One of the criteria for the optimum amplitude characteristics of EIT applied systems may be the degree to which the two conditions are satisfied: maximum total number of different halftone gradations and the necessary nature of the change in the CS over the dynamic range of the image being transmitted.

3. The amplitude characteristics of the transmitting and receiving channels of the EIT system, which are optimal in this sense, may be found when the characteristics of the noise sources in the system are known during the solution of the variational problem for a conditional extremum [system (10)]. This optimization of the amplitude characteristics is advantageous when designing applied EIT systems.

4. The same procedure may be used to solve problems for optimization of the amplitude characteristics of one receiving channel, when the amplitude characteristics of the transmitting channel are given, which is important when processing a video signal at the receiving end.

5. One important prerequisite for the correct solution of these problems is the determination of the function  $K_R$ , which characterizes the dependence of the receiver contrast sensitivity on the signal characteristics and the characteristics of the image noise. /10

#### REFERENCES

1. Orlovskiy, Ye. L. Teoreticheskiye osnovy fototelegrafirovaniya (Theoretical Bases of Photographic Telegraph Transmission). "Svyaz'izdat", 1957.
2. Lebedev, D. S., and I. I. Tsukerman. Televideniye i teoriya informatsii (Television Transmission and Information Theory). "Energiya", 1965.
3. El'sgol'ts, L. E. Variatsionnoye ischisleniye (Variational calculus). GITTL, 1958.

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